Title of Investigation:

Reconfigurable Tetrahedral Walker

Principal Investigator:

Dr. Steven A. Curtis (Code 695)

Other In-house Members of the Team:

Dr. Cynthia Y. Cheung (Code 695), Nicholas M. Shur (Code 544) and Gary L. Brown (Code 544)

Other External Collaborators:

None

Initiation Year:

FY 2004

Aggregate Amount of Funding Authorized in FY 2003 and Earlier Years:

$0

FY 2004 Authorized Funding:

$35,000

Actual or Expected Expenditure of FY 2004 Funding:

In-house: $20,000 for Code 547 fabrication; $15,000 for tetrahedral walker parts

Status of Investigation at End of FY 2004:

To be continued in FY 2005 with funds remaining from FY 2004 and earlier years

Expected Completion Date:

September 2005

Purpose of Investigation:

The goal of this investigation is to develop a conceptual design and electro-mechanical control scheme for the four-tetrahedra (4-TET) walker. The investigation is part of a three-tiered effort to develop a new kind of structural system that can change its form to improve its function or adapt better to its environment. The three-tiered effort will produce materials called ART, MART, and SMART. ART, which stands for Addressable Reconfigurable Technology, is a system of interconnecting reconfigurable nodes and struts made of macroscopic electromechanical systems (EMS). ART can be progressively downsized to micro- (MEMS) ART (MART), and nano- (NEMS) or Super Miniaturized ART (SMART). This highly integrated three-dimensional mesh of actuators and structural elements can reconfigure to provide a variety of functions without the need for specialized appendages, like legs or arms.

The fundamental unit of the ART/MART/SMART device — a reconfigurable tetrahedron — is already being prototyped through a joint effort involving Code 695 and Code 544. This minimal design is sufficient to demonstrate the advantage of a mobile platform with no top or bottom and no back or front. The walker moves by tumbling, and therefore cannot fall down and not get up. The walker can stretch or contract to conform to terrain, and therefore, can go where no wheels dare to go. We present here the results of our efforts to take the next step — the design and development of a prototype four-strut walker as a mobile platform to carry a payload in the central node.

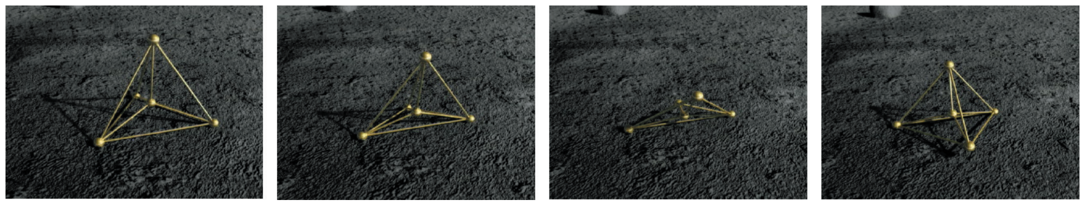

Figure 1. The 4-TET in motion

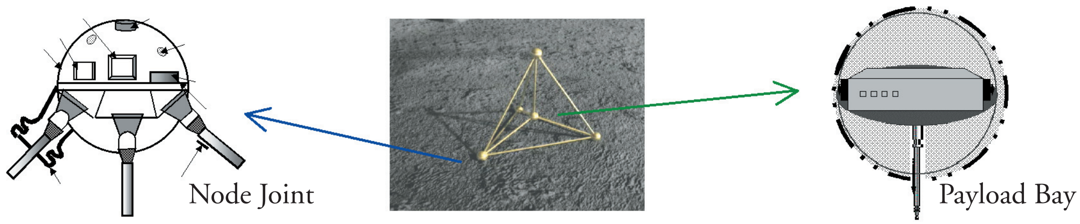

Figure 2. 4-TET conceptual design

FY 2004 Accomplishments:

We have just demonstrated the single walking tetrahedron prototype, which acts as a "proof of concept" for the strut deployment mechanism. We have developed a preliminary conceptual design of a 4-TET that carries an astrobiology payload in its central node. This design was created for a proposed Astrobiology Science and Technology for Exploring Planets (ASTEP) field campaign in Iceland. The design includes:

- Node joints to accommodate struts, control electronics, and actuation mechanisms
- A node shroud to prevent debris from entering joints
- Both active and passive control options for the payload attachments
- A payload bay with a double sliding sphere enclosure. The outer shell provides a protective cover and the inner shell is self-righting with weights at the bottom. An opening at the bottom of the sphere allows the deployment of a science probe for in-situ data acquisition, and
- Preliminary 4-TET remote control electronics.

We have simulated ART structures at EMS (simple tetrahedra), MEMS (multiple tetrahedra), and NEMS (continuous space filling structures) levels. Last, we have developed a conceptual design for 12 Tetrahedral Walker.

Planned Future Work:

5-10 years:	ART using conventional EMS and metal struts, real density < 1 kg/m^2 (Walking Multi-tetrahedra)
10-15 years:	Micro Addressable Reconfigurable Technology (MART) using MEMS and carbon composite struts, areal density < 100 g/m^2 (Lunar Lander, Amorphous Rover, Antenna)
20-25 years:	SMART using NEMS and carbon nanotube struts, areal density < 10 g/m^2 (Solar Sails, Fully Autonomous Pico spacecraft and manufacturing, Self- repairing structures)

Summary:

The 4-TET is a first application of the reconfigurable tetrahedral-based robotics as a mobile science platform. It has no top or bottom, no back or front, and therefore, cannot fall down and not get up. The 4-TET can stretch or contract to conform to the terrain and is ideally suited for exploring rugged regions on lunar and planetary surfaces. The technology will support the Vision for Space Exploration Initiative and allow the Goddard Space Flight Center to develop unique in-house skills building and operating these rovers, including electro-mechanical systems, control and power engineering, operation of complex reconfigurable systems, and development of MEMS planetary instruments and sensors. By the end of the performance period, we will demonstrate the operation of the 4-TET as a mobile science platform. However, uncertainties in the technological advances in materials science and intelligent system research may affect the availability of cost-effective tetrahedral-based ART (Addressable Reconfigurable Technology) and MART (MEMS ART) structures and controllers for full implementation in the Exploration Initiative. This constitutes a risk factor that could prevent us from achieving success.